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Evaluation of ALDOT Ditch Check Practices using Large-Scale Testing Techniques

Large-scale Channel Testing
(ASTM D 7208 – modified)
of
Evaluation of a Stacked Wattle Installation Configuration
over
Poorly Graded Sand

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EXECUTIVE SUMMARY

Linear construction typically uses drainage conveyances (i.e., roadside ditches) to convey stormwater runoff away from construction sites to neighboring water bodies. These may not be stabilized and are highly susceptible to erosive shear stresses imposed by high velocity runoff. Many products and practices are available to use as ditch checks to impound runoff, reduce flow velocity, and protect earthen conveyance channels from erosive shear stresses resulting from high velocity flow. Wattles consist of products that are manufactured with many different materials and sizes. An enhanced wattle ditch check installation was evaluated and presented to ALDOT for consideration and approval. This enhanced installation was intended for wattles categorized as 20 in. (51 cm) diameter wattles. However, smaller diameter wattle products are also currently on ALDOT's List II-24. The same wattle ditch check installation practice was used to test the two smaller diameter wattles (i.e., Erosion Eel™ and Filtrexx Filter Soxx™) using a stacked installation. The stacked installation, made up of three total wattles, consisted of two wattles positioned perpendicular to flow and one wattle placed on top of the seam created by the bottom two wattles, thereby resulting in a pyramid shaped, stacked installation. This installation created impoundment lengths, and *EGL* and *y/E* ratios similar to the larger 20 in. (51 cm) diameter wattle products. These are shown in Table 1 for both flow conditions of 0.56 cfs (16 L/s) and 1.12 cfs (32 L/s). It is therefore recommended, that smaller diameter products be installed in a stacked configuration using the same installation procedure recommended for 20 in. (51 cm) diameter wattles.

Table 1: Summary of Test Results for Stacked Wattle Installation at 0.56 and 1.12 cfs.

Installation Type	Avg. Impoundment Length (ft)		Avg. Subcritical EGL Slope (ft/ft)		Avg. y/E Ratio (ft/ft)	
Flow (cfs)	**0.56**	**1.12**	**0.56**	**1.12**	**0.56**	**1.12**
Stacked Wattle Avg.	21.4	28.7	-0.0174	-0.0162	0.97	0.98
20 in. Wattle Avg.	16.0	21.4	-0.0240	-0.0218	0.89	0.93

Note: 1. 20 in. Wattle Avg. is the average performance of all wattles evaluated in Final Report 1 on ALDOT List II-24

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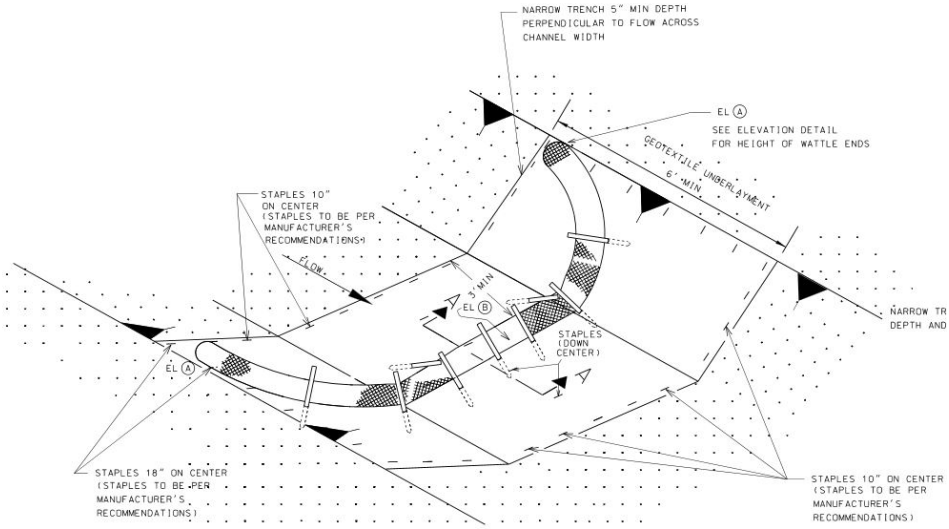
1 INTRODUCTION

The construction of roadways typically consists of mass clearing and grading leaving many site areas unstable, lacking ground cover to protect against rainfall induced erosion. As linear roadway projects progress, unstabilized areas (i.e., roadbeds, cut and fill slopes, and other embankments) tend to be highly compacted thereby reducing infiltration. This may increase sediment-laden surface stormwater runoff from these unstabilized areas. Stormwater runoff from unstabilized grading operations on construction sites can yield sediment losses of 35 to 45 tons/acre (13 to 16.5 tonnes/hectare) per year (*1*). Eroded sediment from construction sites is one of the most harmful pollutants to the environment resulting in over 80 million tons (73 million tonnes) of sediment washing from construction sites into surface water bodies each year (*2*). In linear construction, stormwater runoff is typically diverted to a series of constructed stormwater conveyances (i.e., berms, swales, and ditches), which may also be unstabilized prior to vegetative establishment. Therefore, runoff control measures must be installed to minimize channel erosion, especially during peak periods of a storm event. Stormwater runoff control is the practice of managing concentrated flows and reducing peak runoff caused by modification of the site topography.

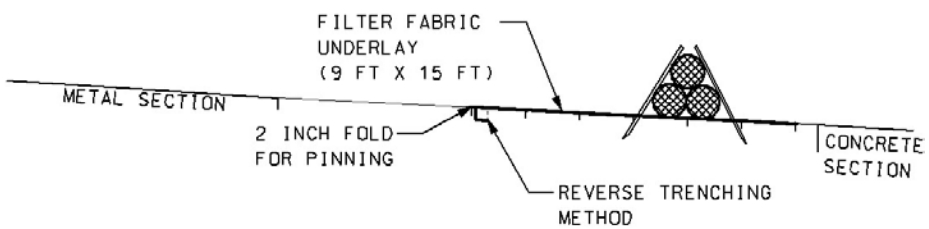
Ditch checks, which are runoff controls, are defined as either permanent or temporary structures constructed across runoff conveyances, intended to slow and impound stormwater runoff, reduce shear stresses that cause channel erosion, and create favorable conditions for sedimentation (*3*, *4*, *5*, *6*, & *7*). A wattle is a manufactured, tubular device composed of natural or synthetic fillers (i.e., mulch, compost material, wheat straw, excelsior [wood shaving], coir, carpet fiber, or recycled rubber tires) encased in a natural fiber or synthetic netting. These products also vary by size ranging in nominal diameters from 9 to 20 in. (23 cm to 51 cm). The advantages of using wattles as ditch checks, over other types of ditch checks (i.e., rock, hay bales, silt fence, etc.) include: (1) its biodegradability, (2) typically lightweight, (3) ease of installation using minimum resources, (4) economical, and (5) available in various dimensions making them adaptable to site specific constraints. Some limitations of using wattles as ditch checks include: (1) their elliptic shape may reduce surface area available for ground contact with the channel resulting in undermining and scour, and (2) the potential for lightweight wattles becoming buoyant, reducing adequate ground contact while subjected to concentrated flows. The purpose of this report is to examine and summarize the effects of a proposed stacked wattle installation using the same installation procedure used for 20 in. (51 cm) nominal diameter wattles developed by the researchers at the Auburn University Erosion and Sediment Control Testing Facility (AU-ESCTF).

2 WATTLE INSTALLATION

ALDOT's newly adopted standard wattle ditch check installation can be found on '*ESC-300 Ditch Check Structures, Typical Applications, and Details*' (*4*) and is shown in Figure 1(a). The adopted standard wattle ditch check installation was used to develop the proposed stacked wattle ditch check installation as detailed in Figure 1(b).



(a) ALDOT New Standard Wattle Detail (*4*)



(b) Proposed Stacked Wattle Installation

Figure 1: Comparison of ALDOT Std. and Proposed Stacked Wattle Installation Practices.

ALDOT's new wattle installation specifies a 20 in. (51 cm) diameter wattle placed perpendicular to flow across a trapezoidal channel. An 8 oz. nonwoven filter fabric underlay 9 ft by 15 ft (2.7 m by 4.6 m) is placed in the channel to protect the wattle/channel bottom interface from erosion and undercutting. The filter fabric is trenched a minimum of 4 in. in using a reverse trenching method as shown in Figure 1(b). A two inch fold should be used to secure the upstream edge of the filter fabric. The two inch fold consists of pulling fabric upstream two inches once the fabric has been secured in the trench. This fold is pinned to the channel to avoid pinning the filter fabric through the trench which may be looser the upstream, undisturbed portion of the channel. The wattles are to be staked in place using a teepee or A-frame method that is nondestructive and secures the wattles in place allowing the practice to intercept channelized flow.

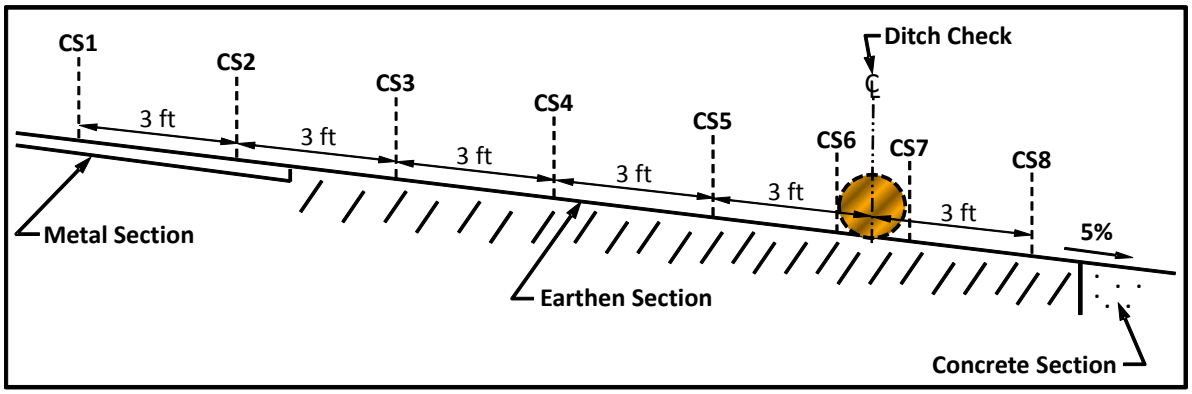
3 TESTING METHODOLOGY

All tests conducted as part of this research were performed at the Auburn University Erosion and Sediment Control Facility (AU-ESCTF) located at the National Center for Asphalt Technology (NCAT) in Opelika, AL.

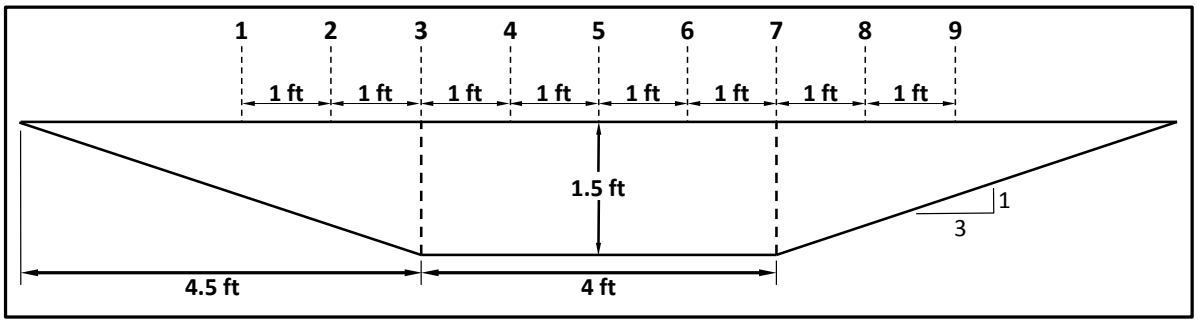
The standard test method referenced for the development of the testing methodology used in this study was ASTM D 7208-06: *Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion* (*7*).

3.1 Test Channel

The AU-ESCTF has a test channel dedicated to performance testing of ditch checks in channelized flow applications and is shown in Figure 2(a) and (b).



(a) Elevation View



(b) Cross-Sectional View

Figure 2: Ditch Check Test Channel Dimensions and Configuration.

The ditch check testing channel has a trapezoidal cross-section with a top width of 13 ft (4 m) and a bottom width of 4 ft (1.2m) with 3H:1V side slopes. The depth of the channel is 1.5 ft (0.5 m) and is 39.5 ft (12 m) long. The channel is divided into a galvanized steel plated section 24.5 ft (7.5 m) long and an earthen section 15 ft (4.6 m) long. The longitudinal slope of the channel is 5%. The earthen section allowed for field quality installations and performance observations of the ditch checks. The metal lined portioned allowed the ditch checks to be tested regardless of channel performance.

3.1.1 Preparation of the Test Channel

Before each test, the 15 ft (4.6 m) earthen section is tilled using a rear tine tiller, hand raked, hand tamped, and then mechanically compacted using an upright rammer hammer with a compaction plate of 14 x 11.5 in. (36 x 29 cm), a blow count of 600 blows/minute and a compaction force of 2,700 lbs (1,225 kg). The soil within the earthen section was classified as a poorly graded sand using the USCS Soil Classification System. The maximum density of 123.8 lbs/ft^3 (19.44 kN/m^3) was determined by the method described in ASTM D698-07, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort* (*8*). In-place density samples were taken with a density drive hammer and thin walled Shelby tubes to verify that at least 95% of standard Proctor density was achieved.

3.2 Two Tier Test Flow Rates

The tests for the proposed stacked wattle installation evaluations used a two tiered flow rate of 0.56 cfs (16 L/s) and 1.12 cfs (32 L/s) for 15 minutes each for a total duration of 30 minutes. Prior to testing, eight level string lines were stretched across the channel at 8 cross-sectional (CS) locations six upstream and two downstream of the ditch check. The measurement points were spaced 1 ft (0.3 m) apart along each string line. These string lines were used to take water depth and velocity

measurements at points in the center of the channel and 1 ft (0.3 m) laterally from the centerline during each test.

3.3 Installation Evaluation Regime

A series of constant flow, large-scale ditch check experiments were performed to evaluate the installation configuration. The Erosion Eel™ and Filtrexx Filter Soxx™ were each evaluated by 3 clean water tests and 1 sediment-laden test for a total of 8 tests. New product was used for each installation test performed, for a total of 24 wattles used during this testing effort.

3.3.1 Materials for Installations

The following is a list of materials used for the various wattle installation configurations:

- *wattle*: 9 to 12 in. (23 to 30 cm) diameter, 10 ft (3 m) long wattles (Note: dimensions nominal),
- *wooden stakes*: 1 in. x 2 in. x 3 ft (2.5 cm x 5 cm x 1 m), used to secure the wattles in place,
- *sod pins*: 11 gauge metal, 6 in. long x 1 in. (15 cm x 2.5 cm) round top pins, used to secure the filter fabric underlay, and
- *filter fabric (FF) underlay*: 8 oz. (225 gram), nonwoven FF, 9 ft (3 m) long, 15 ft (4.6 m) wide. Extends 3 ft (1m) upstream from the upstream face of the wattles and keyed in a minimum of 5 in. (0.13 m) deep in a trench. The fabric underlay extends 3 ft (1 m) downstream beyond the wattles. The trenched end of fabric uses a reverse trenching method which is recommended for rolled erosion control products by American Excelsior Company® as shown in Figure 3 (*9*). The upstream and downstream edges of FF were secured with sod staples spaced 10 in. (25 cm) apart and longitudinally along each side and the centerline of the fabric spaced 1.5 ft (0.45 m).

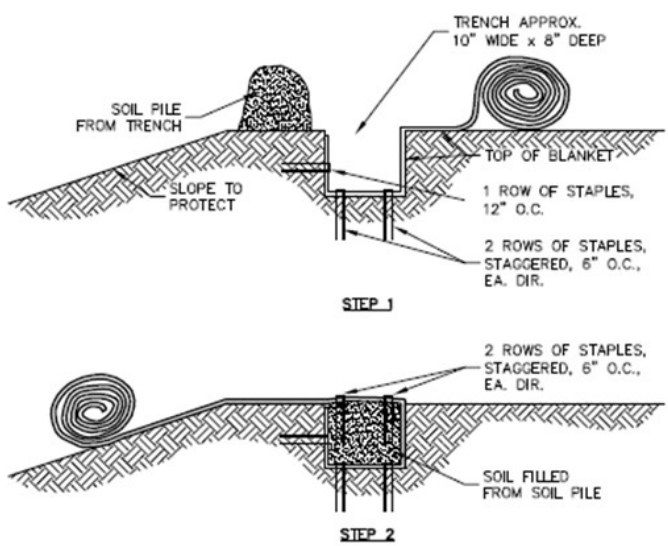


Figure 3: American Excelsior Erosion Control Blanket Trenching Method (*9*)

3.3.2 Stacked Wattle Installation Tests

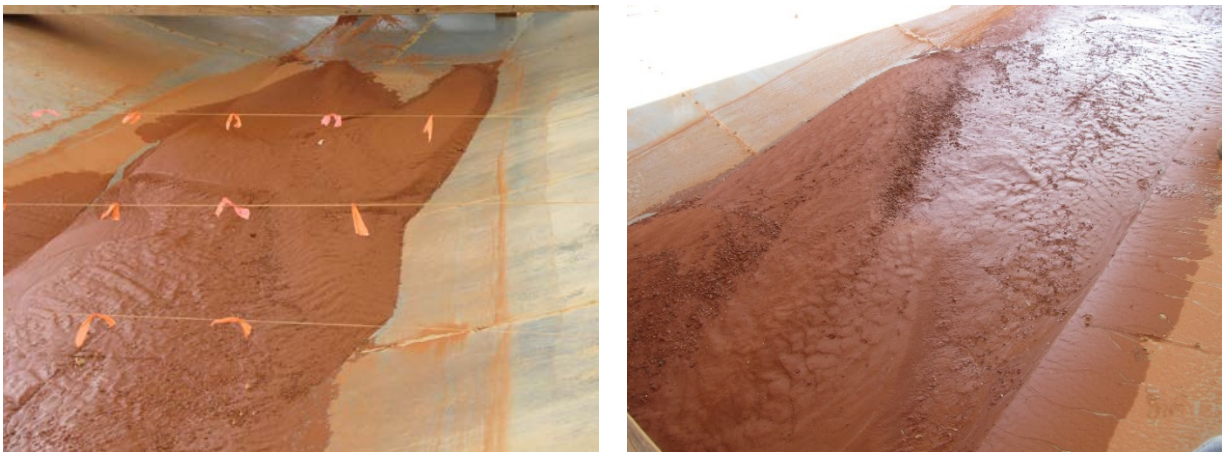
The channel was prepared to experimental specifications for all tests performed on the stacked wattle installation configurations so direct comparisons could be made with the 20 in. wattle tests. Figure 4 provides a photographic comparison of the two products (Erosion Eel and Filtrexx Filter Soxx) used for the stacked wattle installation tests using clean water flow. Figure 5 exhibits that deposition patterns created by the stacked installations at the conclusion of the sediment-laden performance tests.

(a) Erosion Eel stacked installation (b) Filtrexx Filter Soxx stacked installation

(c) Erosion Eel clean water at 0.56 cfs (d) Filtrexx clean water at 0.56 cfs

(e) Erosion Eel clean water at 1.12 cfs (f) Filtrexx clean water at 1.12 cfs

Figure 4: Stacked Wattle Installation Performance Tests.



(a) Erosion Eel sediment-laden test deposition (b) Filtrexx sediment-laden test deposition

Figure 5: Sediment-laden Performance Test Results on Stacked Wattle Installations.

3.4 Data Collected

Once steady-state flow conditions were achieved, water depth and velocity measurements were taken at cross sectional measurement points 4, 5, and 6 for every cross section (CS1-CS8) shown in Figures 2(a) and 2(b). These points were averaged to determine the average water depth and average velocity for each cross section. The distance from the upstream face of the wattle to the hydraulic jump was also recorded once steady state conditions were achieved to determine subcritical flow length created by the installation's ability to impound water.

Using the collected data, the slope of the energy grade line (*EGL*) for the water profile was plotted as specified by ASTM D 7208-06. The EGL is defined by Equation 1 (*7*).

$$EGL = WSE + v^2/2g \qquad \text{(EQ. 1)}$$

where,

EGL = energy grade line (ft)
WSE = water surface elevation (ft)
v = average water velocity (ft/sec)
g = gravitational constant (32.2 ft/sec^2)

The specific energy was also determined from the velocity and water depth measurements. Specific energy is defined by Equation 2.

$$E = y + v^2/2g \qquad \text{(EQ. 2)}$$

where,

E = specific energy (ft)
y = water depth (ft)
v = average water velocity (ft/sec)
g = gravitational constant (32.2 ft/sec^2)

Previous product and practice evaluations have relied upon evaluating the length of impoundment pools and the slope of the energy grade line created by the flow interruption of the ditch checks. Though ASTM D 7208 requires plotting the slope of the energy grade line, there are no discussion or instructions for interpreting the fitted line. Therefore, AU-ESCTF has proposed a different evaluation tool for ditch checks. Using the water depth and specific energy, a ratio of y/E yields a metric that can be used to evaluate overall performance when this value is compared to the theoretical function of y/E vs the Froude number. The Froude number is shown in Equation 3.

$$Fr = \frac{v}{\sqrt{gD}} \quad \text{(EQ. 3)}$$

where,

Fr = Froude number
v = average velocity measured for each cross section (ft/sec)
g = acceleration due to gravity (32.2 ft/sec^2)
D = hydraulic depth (ft)

The function created by y/E and Fr is a 3rd order polynomial with an inflection point that occurs at approximately y/E = 0.75. This inflection point designates the change in flow behavior of the channelized flow that is restricted by the ditch check. Measurements were taken at 3 ft intervals for 15 ft upstream of the ditch check to determine an average ratio of y/E. Using the location of the inflection point occurring in the function for the Froude number and y/E ratio, a minimum criteria of y/E equal to 0.75 was identified as the point at which the hydraulic behavior changes from velocity driven flow to depth dominated flow. Refer to *Research Report No. 6 for ALDOT Project: 930 – 826R (10)* for a more complete discussion and analysis of this criteria.

4 RESULTS AND DISCUSSION

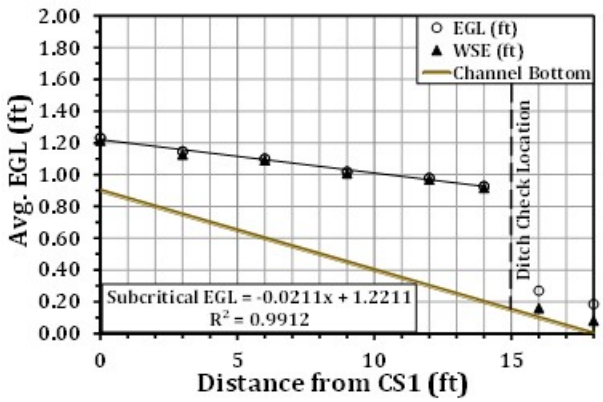
The following section is a summary of the results and comparisons that were made from the experiments using a two tier flow regime of 0.56 and 1.12 cfs for 15 minutes each for a total test duration of 30 minutes.

The stacked wattle installation evaluation was performed using the two products with diameters smaller than the 20 in. nominal diameter requirement currently approved by ALDOT: (1) Erosion Eel and (2) Filtrexx. Each installation was comprised of three wattles setup in a stacked formation with two wattles as the base and one wattle as the top forming a pyramidal shape to create a taller ditch check installation. Both products were installed using the same adaptation of the newly adopted standard ALDOT wattle ditch check installation.

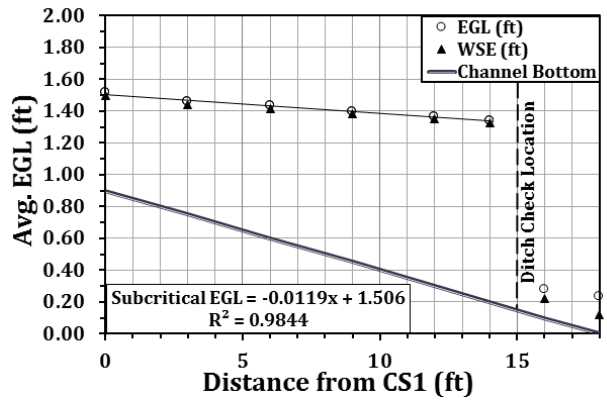
As Figure 6(e) and 6(f) show, the average stacked wattle installation performs slightly better than the average performance for all seven 20 in. wattles tested during this research effort. It should be noted that as shown in Table 2, the Erosion Eel and Filtrexx Filter Soxx products are heavier and denser than any of the 20 in. diameter wattles, having an average density of 2.8 lbs/ft^3. Since these products are much denser than the 20 in. wattles, the stacked wattle installations were able to impound water to a degree similar to the heaviest and most dense 20 in. wattles.

Table 2: Average Measured Product Dimensions

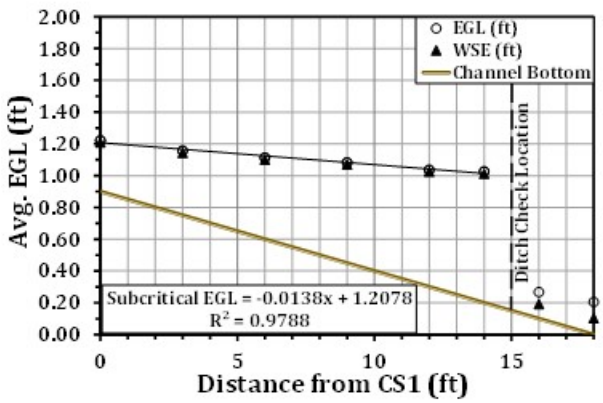
Product	Avg. Length (ft)	Avg. Diameter (in.)	Avg. Weight (lbs)	Avg. Density (lbs/ft^3)
Erosion Eel	9.5	9.4	137.1	30.2
Filtrexx Filter Soxx	10.6	10.4	92.0	14.9



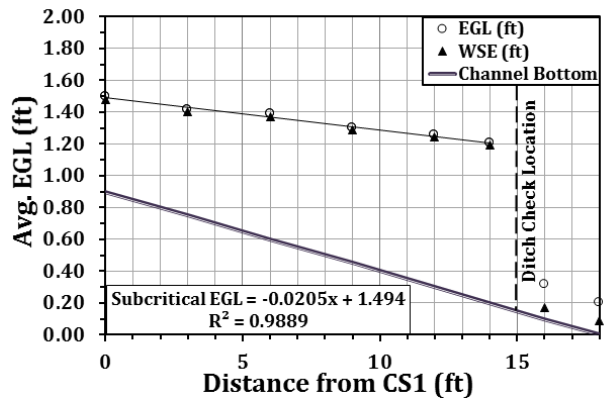
(a) Erosion Eel Average EGL (0.56 cfs)



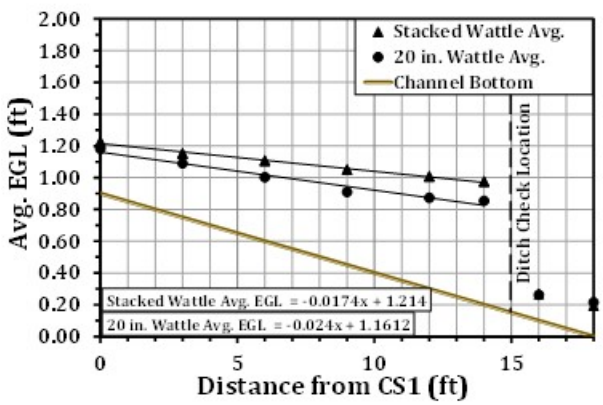
(b) Erosion Eel Average EGL (1.12 cfs)



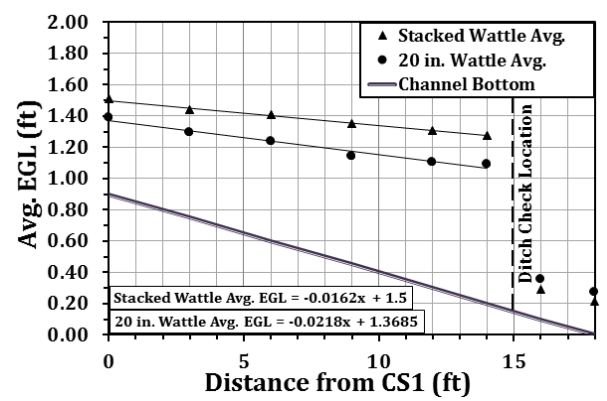
(c) Filtrexx Filter Soxx Average EGL (0.56 cfs)



(d) Filtrexx Filter Soxx Average EGL (1.12 cfs)



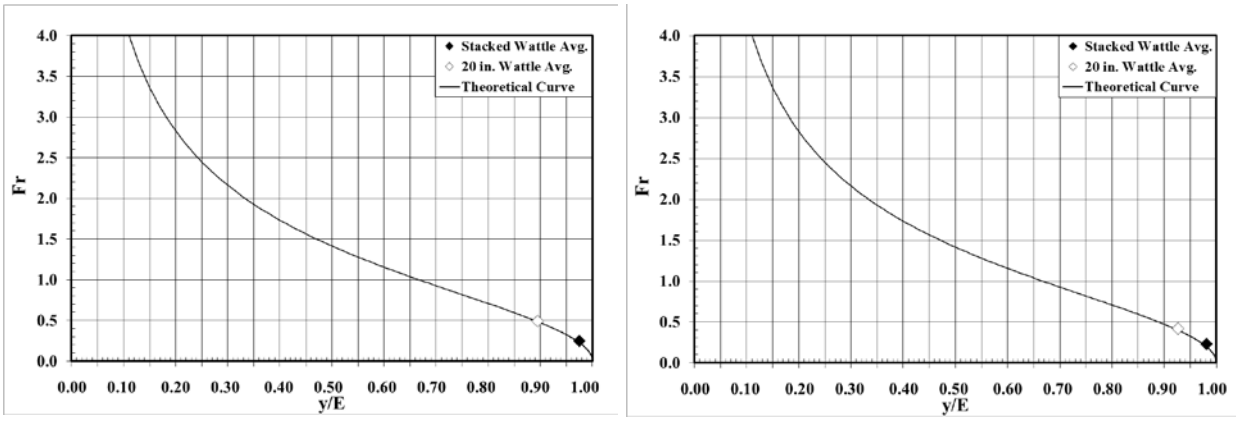
(e) Stacked vs. 20 in. wattle average EGLs (0.56 cfs)



(f) Stacked vs. 20 in. wattle average EGLs (1.12 cfs)

Figure 6: Comparisons of Average EGLs for Various Product Installations.

Using the performance criteria of *y/E*, the average performance of the 20 in. diameter wattle installation was compared to the average performance of the stacked installation for both flow tiers, as shown in Figure 7. The average *y/E* for the stacked wattle installation was 0.97 and 0.98 for low and medium flow, respectively. The *y/E* for the 20 in. wattle installation was determined to be 0.89 and 0.93 also for low and medium flow, respectively. The *y/E* of the 20 in. wattles is skewed by the excelsior wattles that are high flow through and create much lower *y/E* ratios even at higher flow rates.



(a) 0.56 cfs (low flow) (b) 1.12 cfs (high flow)

Figure 7: Performance Criteria for Avg. 20 in. and Stacked Wattle Installations.

5 CONCLUSIONS

As this study has shown, the stacked wattle installation is capable of creating favorable conditions for impounding water, reducing flow velocity, and increasing water depth. These conditions help protect earthen channels from erosive forces and create conditions favorable for sedimentation to occur. The stacked installation resulted in a *y/E* ratio of 0.98. Each product used for this installation study also resulted in a *y/E* ratio of 0.98 for flows at 1.12 cfs. Both of these *y/E* ratios are closer to 1 than the average *y/E* for the standard 20 in. wattle installation. This is most likely due to the density of the products used, rather than the installation. However, the installation does allow the products to perform as intended and therefore is effective as a stacked wattle ditch check practice.

6 RECOMMENDATIONS FOR IMPLEMENTATION

As a result of this testing effort, the research team recommends a stacked installation using smaller diameter wattles that employs the same installation practices used for the standard 20 in. wattle installation. This installation practice includes using the teepee, nondestructive staking pattern and an 8 oz. filter fabric underlay to minimize undercutting and protect the channel | wattle interface from erosion. The recommended installation will consist of three smaller diameter wattles using a stacked installation comprised of two wattles lined up perpendicular to flow and one wattle placed on top of the seam generated by the bottom two wattles creating a pyramid shaped, stacked installation. From this study, it is apparent that this installation practice will yield similar hydraulic performance as the standard 20 in. wattle installation and will keep installation practices simple and not require separate installations for the 20 in. and stacked installation.

7 REFERENCES

1. America Society of Civil Engineers (ASCE) and Water Environment Federation (WEF), *Design and Construction of Urban Stormwater Management Systems*, ASCE Manuals and Reports of Engineering Practice No. 77, WEF Manual of Practice FD-20, 1992.
2. Novotny, V. 2003. Water Quality: Diffuse Pollution and Watershed Management. New York: John Wiley & Sons, Inc.
3. U.S. Environmental Protection Agency (EPA), *Menu of BMP's: Check Dams,* May 2006 http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm. Accessed February 9, 2012.
4. *ESC-300 Ditch Check Structures, Typical Applications and Details*, Alabama Department of Transportation (ALDOT), Montgomery, AL, 2012, sheets 1 & 4 of 7.

5. *Temporary Rock Silt Check Type B Specification, Erosion Control and Roadside Development*, North Carolina Department of Transportation (NCDOT), Raleigh, NC, 2012, 1633.01.
6. *Manual for Erosion and Sediment Control in Georgia*, Georgia Water and Soil Conservation Commission (GWSCC), Athens, GA, 2000, pg. 7 of chapter 2.
7. ASTM Standard D7208, 2006, *Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion*, ASTM International, West Conshohocken, PA, 2007.
8. ASTM Standard D698, 2007, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort*, ASTM International, West Conshohocken, PA, 2007.
9. American Excelsior Company: Earth Science Division. *Technical Support Library: AEC Premier Straw Slope,* http://www.americanexcelsior.com/ErosionControl/library/CAD%20Details/AEC%20Premier%20Straw%20Slope.pdf
10. Zech, W.C., Fang, X., and Donald, W.N. (2014). *HRC Research Report 6: Performance Criteria Report,* ALDOT Project 930-826R: Evaluation of ALDOT Ditch Check Practices using Large-Scale Testing Techniques.